Two New Species of *Astichus* (Hymenoptera: Eulophidae: Entiinae) and Their Ciid Hosts (Coleoptera: Ciidae) in Bracket Fungi on Oʻahu, Hawaiʻi

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Abstract. Two new species of *Astichus* found on Oʻahu island, *A. elauelei* Honsberger & Lorenzo-Elarco **sp. nov.** and *A. elauuli* Honsberger & Lorenzo-Elarco **sp. nov.**, are described. *Astichus elauelei* was observed parasitizing larvae of the endemic *Cis pacificus* in the bracket fungus *Fuscoporia gilva* by direct observation of parasitized larvae. Additionally, it parasitized larvae of an adventive *Xylographus* sp. in the bracket fungus *Earliella scabrosa*, as determined through exposure of sentinel colonies of the spectrum of ciid beetles inhabiting polypores from which the parasitoid had been observed to emerge. A species of Pteromalini (Hymenoptera: Pteromalidae) was also recorded parasitizing larvae of *Cis paritii* in *Trametes versicolor* through direct observation.

Keywords: polypore, parasitoid

The genus *Astichus* Förster, 1856 (Eulophidae: Entiinae) contains beautiful wasps with metallic iridescent sculpture on the head and mesosoma and amoebous or banded patterns on the forewings. They are, in general, known to be associated with bracket fungi or polypores on decaying trees, with a few recorded instances of their parasitism of ciid beetles that inhabit these fungi, confirmed with varying degrees of certainty (Giraud and Laboulbène 1877; De Gaulle 1908; Donisthorpe 1940; Bouček 1963; Tachikawa 1977, 1983, 1984, 1987).

In Hawaiʻi, 50 ciid species have been recorded: 36 in the genus *Cis* Latreille, 1797; 13 in the flightless genus *Apterocis* Perkins, 1900; and one in the genus *Orthocis* Casey, 1898 (Zimmerman 1939, Lawrence 1971, Nishida 2002). The species of *Apterocis* are known only from Hawaiʻi. The recorded species of *Cis* belong mostly to the *pacificus*, *setarius*, and *signatus* species groups as defined by Lawrence (1971, 2016), and most are probably endemic. However, two recorded species of *Cis* are considered adventive: *Cis fuscipes* Mellié, 1849, a

species known to be adventive in many other areas of the world (Lawrence 2016), and an unidentified member of the *Cis bilamellatus* species group (Samuelson 1998, Nishida 2002). Members of the *bilamellatus* species group are primarily continental in distribution, occurring in the Australian, Ethiopian, Neotropical, Oriental, and Palearctic regions; however, they are not known to occur naturally on oceanic islands (Lopes-Andrade and Lüer 2014, Lawrence 2016, Souza-Gonçalves and Lopes-Andrade 2018, Rosa-Oliveira and Lopes-Andrade 2023). The single species of *Orthocis* recorded from Hawai‘i, *Orthocis immaturus* (Zimmerman 1939), was originally described in the genus *Cis* and transferred to *Orthocis* by Lawrence (1971) more than 50 years ago. Based on its original description (Zimmerman 1939), it fits within the limits of *Orthocis* as currently defined, considering the most recent redescription of the genus by Lawrence (2016). Several described species of *Orthocis* occur exclusively on oceanic islands, and numerous undescribed insular species are present in collections (Lopes-Andrade 2010; Lawrence 2016, 2019). Without examination of the type series and additional collection of the species in Hawai‘i, it is premature to determine whether the species is endemic or adventive.

Worldwide, the vast majority of Ciidae feed and reproduce in the basidiomes of macrofungi, typically polypores (Lawrence and Lopes-Andrade 2010, Graf-Peters et al. 2011, Rosa-Oliveira and Lopes-Andrade 2024). Although some endemic Hawaiian species also live in such larger basidiomes, many have a more unusual life history, feeding on microfungi growing on and under the surface of decaying wood (Swezey and Bryan 1929, Swezey 1931, Swezey and Williams 1932, Perkins 1933, Zimmerman 1939, Lawrence and Lopes-Andrade 2010).

Members of *Astichus* can largely be recognized within the eulophid subfamily Entiinae by their association with polypores and by some of the characters that make them so attractive: the metallic head and abdomen, and the often intricately networked or banded wing patterns of hyaline areas and infuscations on the forewings. The genus was divided into two subgenera by Bouček (1963, 1988): *Astichus sensu stricto* and *Closteromphale* (=*Linastichus*). *Astichus s.s.* is recognized by the sculpture on the head and mesosoma finer in some areas than others, with these differences not corresponding to any color stripes; network-like patterns on forewings similar to that of *Astichus arithmeticus* (Förster 1851); the posterior edge of the gastral tergites straight; the propodeum long; and the posterior ocelli located near the posterior of the vertex. *Closteromphale* is defined by having 4–6 dark purple longitudinal stripes on the otherwise metallic blue-green mesosoma and vertex of the head, and dark transverse stripes on the face; the sculpture on head and mesosoma rough raised-reticulate, and even in rugosity except possibly finer on the dark stripes; the forewing with two broad, transverse bands; the posterior edge of the first and second gastral tergites notched medially; the propodeum short; the vertex extending substantially behind the posterior ocelli; and the male antenna with the first funicular segment not nodose. Bouček (1963) placed *Astichus longevittatus* Masi, 1925, from Europe and *Astichus pulchrilineatus* Gahan, 1927, from North America into *Closteromphale*, and Bouček (1988) added *Astichus bilineatus* (Girault, 1915) and *Astichus mirissimus* (Girault 1933), both from Queensland, Australia, into *Closteromphale*. Doğanlar (1992)

described and added *Astichus bachmaeiri* from Corsica. While Bouček (1988) describes the genus *Astichus* as generally bimodal in morphology between these two subgenera, their limits may not be completely well defined. Bouček (1988) notes that *Astichus grootaerti* Bouček, 1988, from Papua New Guinea, and *Astichus townesi* Tachikawa, 1983, from Borneo appear intermediate between the subgenera. Neser (2012), in her description of *Astichus micans*, *Astichus silvani*, *Astichus gracilis*, and *Astichus naiadis* from South Africa, observed that while they all had distinct stripes on the head and mesosoma as in *Closteromphale*, other characters place them intermediate between the two subgenera defined as they are.

Here we report and describe a new species of *Astichus* found parasitizing the endemic *Cis pacificus* Sharp, 1879 and an adventive *Xylographus* sp. previously unrecorded in Hawai‘i, and another new species of *Astichus* also likely associated with *C. pacificus*, on the island of O‘ahu in Hawai‘i. This is the first record of *Astichus* in Hawai‘i. Although a species originally described as *Astichus cyaneus* Ashmead, 1901 is known from Hawai‘i, it was later determined to be taxonomically misplaced and not to belong to Eulophidae (Yoshimoto 1967, Nishida 2002).

Methods

Polypores containing ciid beetles were collected from decaying trees around the island of O‘ahu and placed in emergence boxes or dissected. Parasitoid-host associations were found in two ways. The first was through direct observation and rearing of parasitized hosts from dissected bracket fungi, and the second was by exposing sentinel colonies of potential hosts in polypores to the environment.

Collection of polypores and direct observation of parasitism. Basidiomes of *Fuscoporia gilva* (Schwien.) T. Wagner & M. Fisch (Polyporaceae) containing populations of reproducing ciid beetles were collected from old *Schinus terebinthifolia* Raddi trees near Palikea in the Wai‘anae Mountains of O‘ahu, within approximately 50 m of 21.4145°N, 158.0999°W (elevation approx. 900 m), and later dissected (Fig. 1a–c, f–g).

Bracket fungi were also collected on O‘ahu from near Kahana Bay, the slopes of Wa‘ahila Ridge near the back of Mānoa Valley, Poamoho Ridge in the Ko‘olau mountains, and Maunawili Valley, and watched for emergence of parasitoids and examined for Ciidae present within them.

Determination of parasitoid-host association using sentinel colonies. A variety of ciid species and the two species of *Astichus* described below, along with various other arthropods such as flies, moths, an erotylid beetle, and pseudoscorpions, had been found to emerge from *Earliella scabrosa* (Pers.) Gilb. & Ryvarden (Polyporaceae) growing on a *Ficus microcarpa* tree in an unmaintained area of the campus of the University of Hawai‘i at Mānoa (21.2954°N, 157.8145°W, 15 m) (Fig. 2a). To discover which of these species inhabiting the polypores were being parasitized by the *Astichus*, a separate colony of each ciid species was produced and exposed to the environment, as follows.

Basidiomes with signs of ciid activity were removed from the tree and dissected, yielding seven different morphospecies of Ciidae. Only the morphospecies determined to be hosts of the *Astichus* spp. were identified further (see Results); the remaining species will be treated in a separate work currently in preparation. Other basidiomes with little or no sign of arthropod activity were also removed from the trees, and parts that showed any

arthropod activity, such as bore holes, or areas with topographical features that were hard to check sufficiently for such activity, were cut away to make sure that no arthropods were present within them. These pieces were placed into individual screened glass jars, and individuals of each of the seven morphospecies of Ciidae were separately introduced to one of these pieces. After 12 weeks, the ciids had entered the basidiomes and were clearly active and reproducing inside them. These sentinel ciid colonies were then suspended on strings from a metal hanger tied to a tree branch in a shaded, secluded area of the same tree from which the polypores were taken and parasitoids had been found, approximately 1.5 m off the ground (Fig. 2b), for 72 hours in clear, calm weather from 28 April to 1 May 2020. Each colony was then returned to a screened container to give parasitoids a chance to develop and emerge (Fig 2e).

Species descriptions. Specimens collected from wood and other plant parts were examined and photographed using a Leica MZ16 stereomicroscope or Macropod Pro imaging system. Specimens were also dissected, examined, and photographed using an Olympus CX31 compound microscope. Terminology follows Gibson (1997).

Repositories. Specimens are deposited in the following museums:

BPBM—Bernice Pauahi Bishop Museum, Honolulu, Hawai'i, USA

NHMUK—The Natural History Museum, London, UK

UHIM—University of Hawai'i Insect Museum, Honolulu, Hawai'i, USA

Results

Two undescribed species of *Astichus* were found emerging from the basidiomes collected on O'ahu. Host associations and descriptions follow.

Direct observation of parasitoid-host associations. Many of the basidiomes of *Fuscoporia gilva* collected in the Palikea area of O'ahu contained active populations of ciid beetles in all life stages (Fig 1c). Some of the larvae were parasitized (as in Fig. 1f,g), and adults of *Astichus elauelei* sp. nov. described subsequently, as well as a few other arthropods including Anthocoridae (Hemiptera), Elateridae (Coleoptera) larvae, Thysanoptera, Aranae, and Diplopoda were also found inside. Two species of Ciidae were present: *Cis pacificus* (Fig 1d,e) and *Cis signatus* Sharp, 1879. *Cis pacificus* was found in high densities and was much more prevalent than *C. signatus*, of which only a few adult individuals were found. Actively parasitized larvae, and other parasitoid larvae found inside that had finished consuming their hosts and detached, were reared to the adult stage; all surviving individuals identified as *Astichus elauelei* sp. nov. At least some of the parasitized beetle larvae were clearly associated with *C. pacificus,* given the vast prevalence of that species over *C. signatus*, of which only a few adults were found in total, and the large number of *Astichus elauelei* sp. nov. individuals that eventually emerged from the dissected polypores. *Astichus elauelei* sp. nov. thus utilizes *C. pacificus* as a host in these polypores, and was observed to function as an idiobiont ectoparasitoid. These observations do not preclude that there is also an association with *C. signatus*.

A species of Pteromalini (Hymenoptera: Pteromalidae: Pteromalinae) (*sensu* Burks et al. 2022) was found to emerge from basidiomes of *Trametes versicolor* (L.) Lloyd (Polyporaceae) collected on dead logs on the forest floor in the back of Mānoa Valley on the slopes of Wa'ahila Ridge on O'ahu. Upon dissection, two *Cis* spp. were found in the fungi: a species identified as *Cis paritii* Perkins, 1933 vastly predominate, densely populating

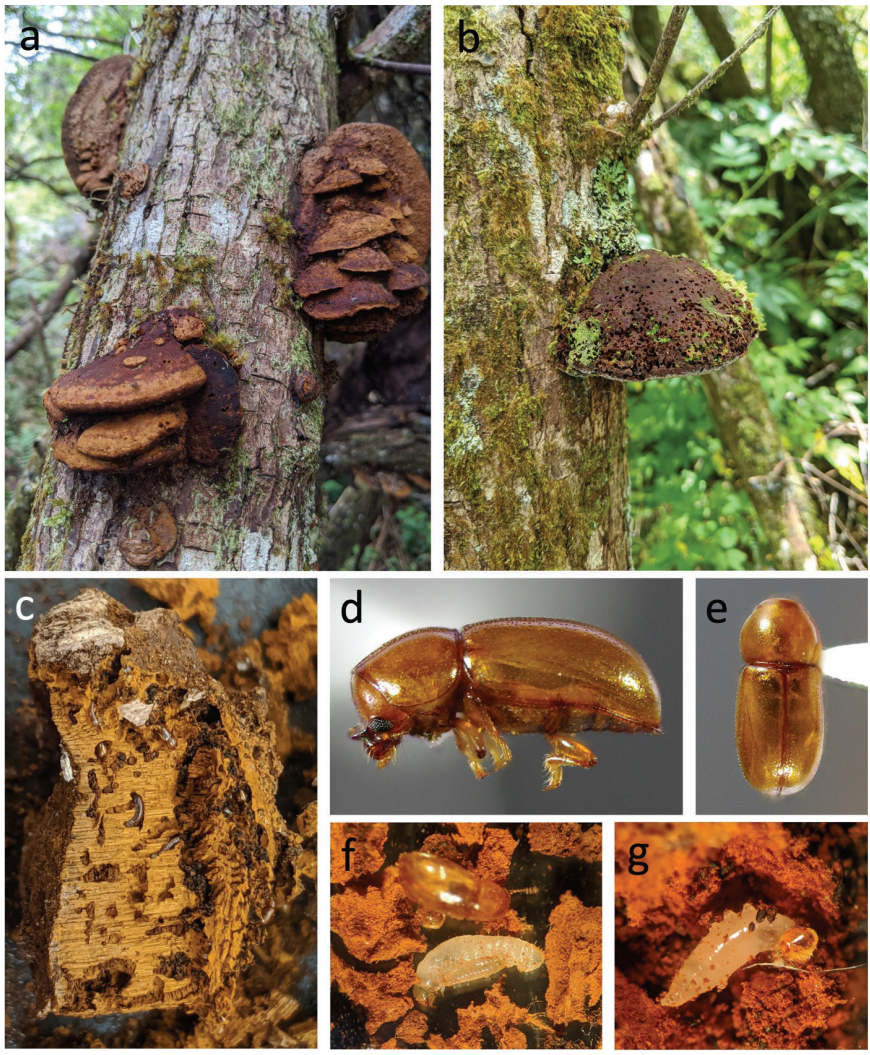

Figure 1. Determination of a host-parasitoid association between *Astichus elauelei* and *Cis pacificus* through direct observation. **a, b:** *Fuscoporia gilva* polypores on *Schinus terebinthifolia* trees in the Palikea area of the Wai'anae mountains of O'ahu from which *Astichus elauelei* emerged. **c:** Polypore broken open, showing ciids in their tunnels inside. **d, e:** *Cis pacificus* adult, lateral and dorsal views. **f, g:** *Cis* sp. larvae parasitized by *A. elauelei*.

the fungi; only two individuals of the other undetermined *Cis* species were found in total. A parasitoid pupa was found in a tunnel with a desiccated ciid larva next to it (Fig. 3a); the pupa was reared and identified as the Pteromalini sp., its host clearly one of the *Cis* spp., likely *C. paritii*.

Determination of parasitoid-host association using sentinel colonies.

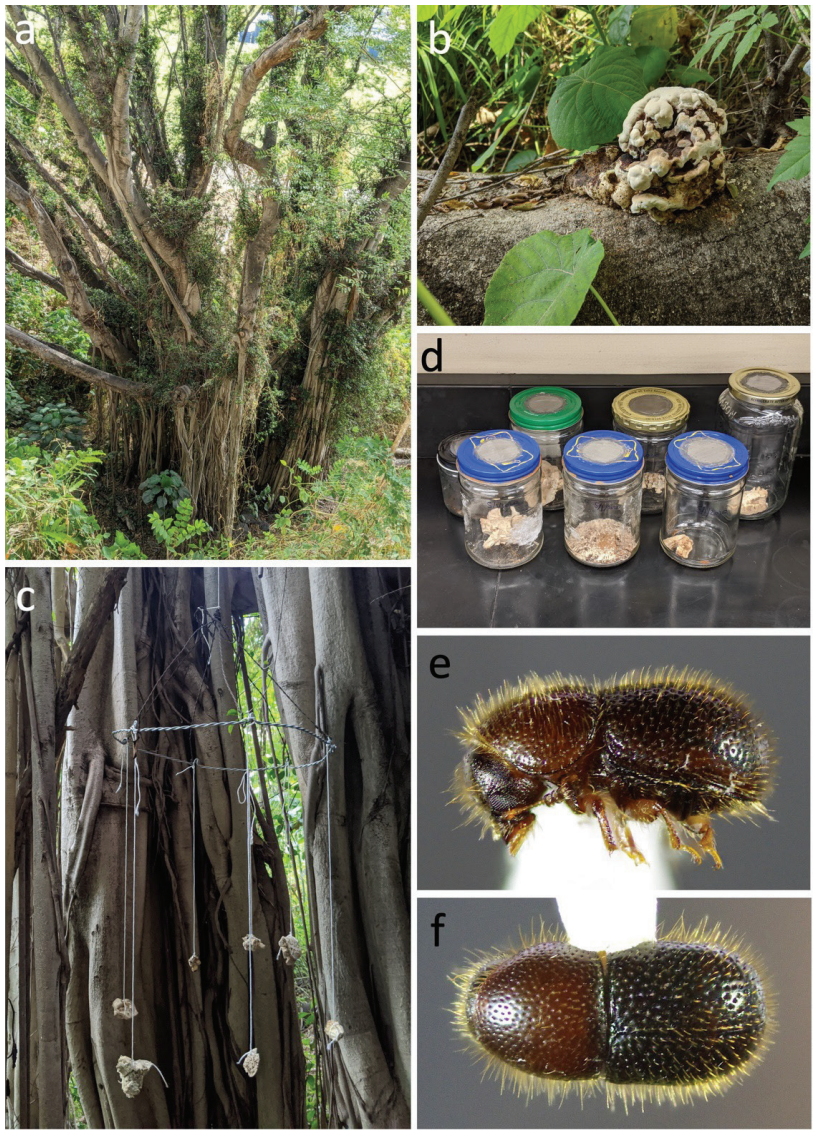

Figure 2. Determination of a parasitoid-host association between *Astichus elauelei* and a *Xylographus* sp. using sentinel colonies. **a**: *Ficus microcarpa* tree in an unmaintained area of the University of Hawai'i at Mānoa, on which the *Earliella scabrosa* polypores containing ciid beetles and *A. elauelei* were found. **b**: close-up of a maturing *E. scabrosa*, largely uninfested by arthropods and used to make sentinel colonies. **c**: Sentinel ciid colonies in pieces of *E. scabrosa* polypores suspended from the tree, each containing only one ciid species of the full spectrum of species found to inhabit the polypores. **d**: The ciid colonies in individual screened containers after exposure to the environment, for parasitoid emergence. **e, f:** *Xylographus* sp. from the sentinel colony from which two *A. elauelei* were found.

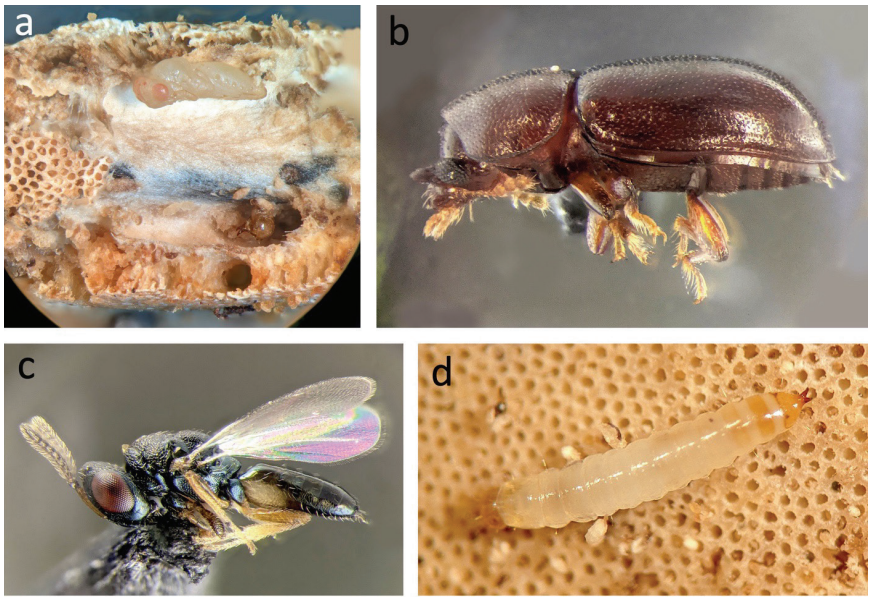

Figure 3. Parasitoid-host association between a Pteromalini sp. and a *Cis* sp. in *Trametes versicolor*. **a:** section of *T. versicolor* broken open to reveal a pupa in a tunnel (top), reared and identified as a Pteromalini sp., with the sclerotized head and posterior of a desiccated ciid larva (bottom) matching that of healthy ciid larvae reared and identified as a *Cis* sp.; **b:** *Cis paritii* adult, the species that vastly predominates the two found in the polypores; **c:** Pteromalini sp. adult ♂; **d:** *Cis* sp. healthy larva.

Thirty-three days after the sentinel colonies had been exposed to the environment, no parasitoids had been observed in the emergence containers, so the fungi were dissected. Inside the colony of a *Xylographus* sp., somewhat deep within the fungal material, two *Astichus elauelei* sp. nov. adults were found. The sentinel colonies were a close replication of the polypores found naturally on trees in the same location, and together presented the parasitoids with the full spectrum of their possible hosts. Thus, it appears that this *Xylographus* sp. is a host of *Astichus elauelei* sp. nov. in naturally occurring *E. scabrosa*. This implication is fairly robust for the following reasons: (1) The basidiome yielding *Astichus elauelei* sp. nov. was completely dissected to observe all its arthropod inhabitants. All were the same *Xylographus* sp., indicating that likely no other species entered that piece of fungus during the time they were exposed to the environment. If another beetle species had entered the fungal body, and left in the time it was exposed, the 72 hours were not enough time for any eggs it might have laid to develop to a stage sizeable enough to act as a host for these parasitoids, which we know from the above observations in natural polypores are idiobiont ectoparasitoids. (2) *Astichus elauelei* sp. nov. kept in captivity and provided with host eggs, larvae, pupae, and adults in bits of fungus have been observed to live for only about a week, which precludes the possibility that they entered the basidiome when it was exposed and lived in it until it was dissected but did not parasitize anything,

unless their lifespan is much longer than had been previously observed. While not conclusive, this very strongly suggests that *Astichus elauelei* sp. nov. utilizes this *Xylographus* sp. as a host. The *Xylographus* sp. appears to be previously unrecorded in Hawai'i.

Astichus elauelei Honsberger & Lorenzo-Elarco sp. nov.

(Figs 4, 5)

Diagnosis: *Both sexes*. Coloration and stripes as in Fig. 4. Forewing with pattern of infuscations as in Fig. 5a, b. Gaster with rugose blue-iridescent patch laterally on anterior segments. *Female.* Antenna with F1–F2 brown, F3–F4 yellow, clava brown. *Male.* Antenna brown, F1 wider than long and closely joined to the base of F2; F2–F4 weakly nodose, apical petiole short; clava formed from three fused segments; a whorl of forward curving setae emerging near the base of each funicle segment and extending slightly beyond the apex of the segment (Fig. 5f). Distinguished from all other described *Astichus* by the combination of the unique pattern on the forewing and coloration of the antennae. In particular, distinguished from the closest species *A. micans*, *A. naiadis*, *A. longevittatus*, and *A. bachmaieri* by: forewing with the apical infuscation solid (in *A. micans* it is separated into disjunct spots) and medial infuscation jagged but of generally even thickness and disjunct from the apical infuscation (in *A. bachmaieri*, *A. naiadis*, and *A. longevittatus* this medial infuscation is convex and connects with the apical infuscation, though faintly in *A. naiadis*); and by females with F3–4 yellow contrasting with the dark brown club and basal funiculars (only F3 yellow in *A. naiadis* and *A. longevittatus*); males with apical petiolar sections of F2–4 shorter (slightly longer in *A. micans*, *A. naiadis*, and *A. bachmaieri*).

Female (Figs 4a–d; 5a, c, e, g–i):

Length: 0.85–1.70 mm; (holotype 1.50 mm)

Head (Figs 4a,b,d; 5e): Iridescent green, gold, copper patterns of fine alveolate sculpture. Vertex with six dark longitudinal stripes; two begin on either side of anterior ocellus and extend straight back to posterior of vertex, running between posterior ocelli; two lateral to these begin where compound eye meets vertex, approximately even with posterior ocelli, and extend to posterior of vertex; two begin on either side of white crossband at apex of scrobal depression and extend diagonally to each posterior ocellus. Three dark spots on inner orbit, sequentially decreasing in size ventrally. Scrobal groove delimited dorsally by carina and white crossband just below anterior ocellus, middle third of white band distinctly thicker than lateral third. Clypeus light brown, similar in color to mandibles and smooth. Face with short setae, setae slightly longer on vertex.

Antenna as in Fig. 5e. Scape yellow-brown medially, lighter basally and at very apex; pedicel dark metallic green; F1, F2, and 3-segmented clava brown, F3 and F4 yellow. F1 and F2 subquadrate, F3 and F4 subrectangular and slightly longer than wide. Length and width ratio of antennal segments approximately Scape (L:W) : Pedicel (L:W) : F1 (L:W) : F2 (L:W) : F3 (L:W) : F4 (L:W) : Clava (L:W) = (4.8:0.8) : (1.9:0.9) : (1.0:1.1) : (1.0:1.0) : (1.3:0.9) : (1.4:1.0) : (3.8:1.6).

Mesosoma (Fig. 4a–c): Metallic, iridescent patterns of green, gold, purple, blue, bronze with alveolate sculpture. Colors generally darkening from dorsal to ventral (with exception of dark longitudinal stripes); pro-and mesonotum green-blue with gold and copper, propodeum copper medially and blue laterally, sides of mesosoma blue-green-purple except for lateral panel of

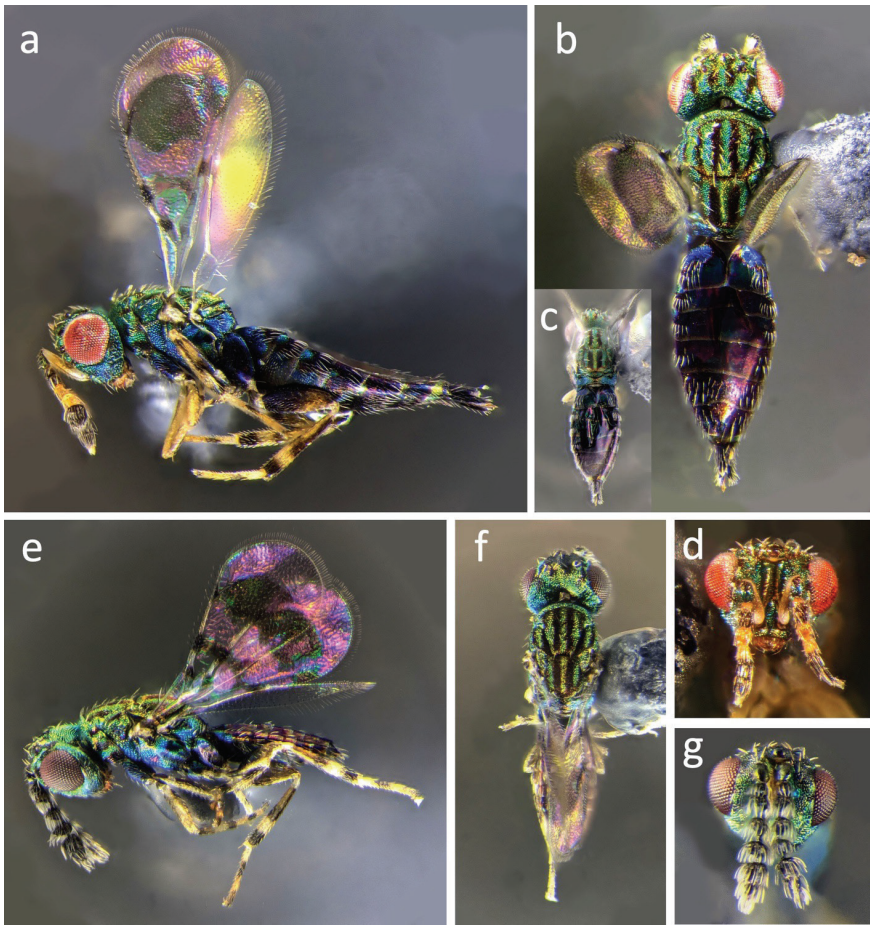

Figure 4. *Astichus elauelei* sp. nov. holotype ♀ **(a–d)** and allotype ♂ **(e–g)**. **a, e:** side view. **b, f:** dorsal view. **c:** propodeum. **d**, **g:** head.

pronotum, which is green, mesopleuron blue-purple, coxae and ventral surfaces blue-purple. Distinct dark longitudinal stripes on mesosoma, as in Fig. 4a–c. Sculpture in general evenly coarse over surface of mesosoma, similar to head, with the exception of mesopleuron, which has sculpture overall finer and two smooth darker purple stripes, and legs and tegula, which have much weaker sculpture. Pronotal collar mesal of lateral panel with line of light-colored rear pointing setae on its posterior margin. Mesoscutum approximately evenly covered with rear-pointing setae of similar length to those on pronotum. Propodeum narrowed mesally so dorsellum and propodeum subequal in length on medial line. Propodeum broadly elevated medially. Length of propodeum on medial line 0.15 times its width in dorsal view, and 0.20 times distance between propodeal spiracles.

Forewing: As in Fig. 5a, subhyaline with the following pattern of infuscations and setae. One small dark brown spot on parastigma and adjacent wing membrane.

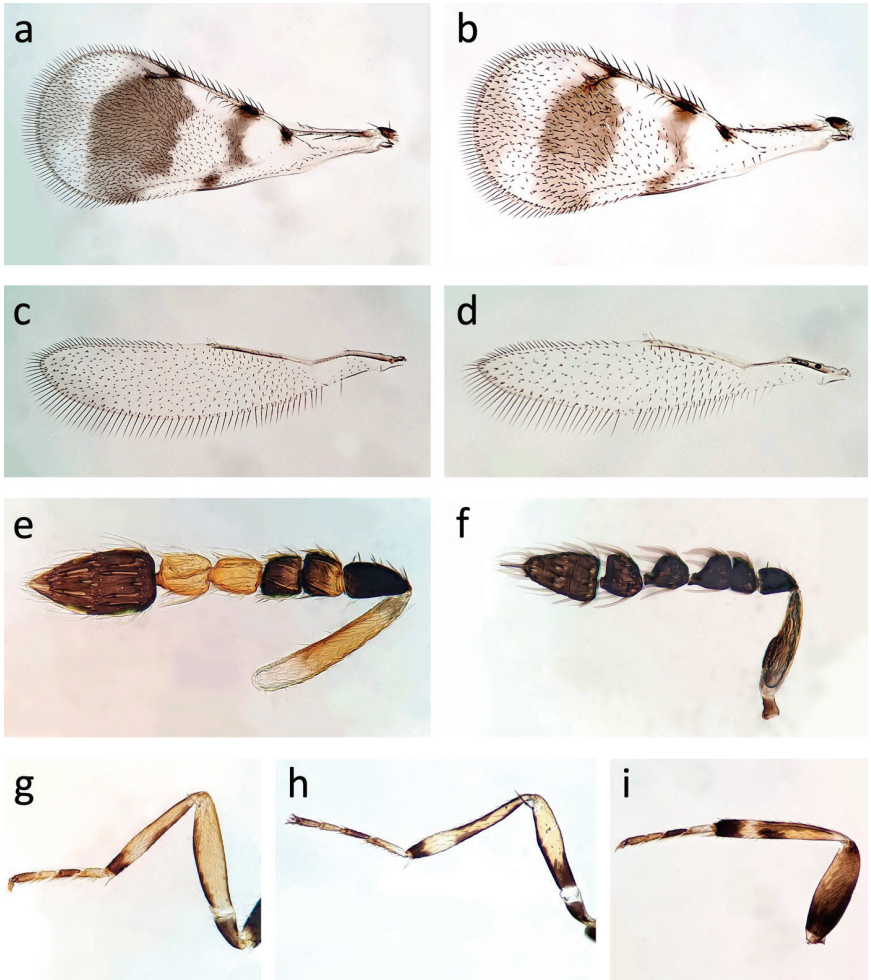

Figure 5. *Astichus elauelei* sp. nov. **a:** forewing ♀. **b:** forewing ♂. **c:** hindwing ♀. **d:** hindwing ♂. **e:** antenna ♀. **f:** antenna ♂. **g:** foreleg ♀. **h:** midleg ♀. **i:** hindleg ♀.

Dark band emerging from a dark spot on marginal vein near its base, just apical of first marginal and admarginal seta; continuing posteriorly as narrow, jagged arc to cubital setal line; then becoming lighter and following cubital setal line apically to a dark, setose spot between cubital and subcubital setal lines near apex of retinaculum. Wider infuscation emerging posteriorly from stigmal vein, junction between stigmal and marginal veins especially dark; apical margin of infuscation continues line of stigmal vein, and then rounds to form broad, convex arc that continues to posterior wing margin, meeting wing margin just apical of where straight trailing edge of wing begins to curve to leading edge; basal margin of infuscation more jagged, beginning as mirror image of stigmal vein and coinciding with margin of speculum, then continuing posteriorly as jagged line,

abruptly turning apically just anterior of cubital setal line to reach wing margin where cubital and subcubital setal lines join. Apex of wing lightly infuscate, lighter than other infuscations; medially connected to infuscation emerging from stigmal vein. The three more-intensely infuscated regions clearly disjunct, separated by subhyaline wing membrane.

Wing membrane setose apical of basal margin of medial dark band, except for speculum which extends length of marginal vein. Cubital setal line intersects subcubital setal line approximately even with end of stigmal vein, just basal of where straight trailing edge of the wing begins to curve, both cubital and subcubital setal lines more or less parallel basally. Marginal setae begin just apical of parastigma. Row of admarginal setae extends from basal margin of medial infuscation to approximately 2/3 length of marginal vein, even with basal margin of infuscation emerging from stigma. Postmarginal and stigmal veins subequal in length; stigmal vein emerges from marginal vein at approximately 30° angle.

Hindwing (Fig. 5c): Membrane subhyaline with no infuscations. Marginal setae on trailing edge with length approximately 1/3 maximum width of wing.

Legs (Fig. 5g–i): Coxae with weakly reticulate sculpture, metallic iridescent blue-black. Femora and tibiae with patterns of brown and yellow, pattern varying slightly among individuals but generally as in Fig. 5g–i. Tarsi with first segment yellow, second segment brown, third segment yellow, and fourth segment slightly darker than third; first through third segments of all legs decreasing in length, fourth segment subequal in length to second.

Metasoma (Fig. 4a, b): Gaster generally shiny, dark, iridescent purple-black; first gastral segment anterolaterally with patch of iridescent blue-purple-green sculpture similar to that on head and thorax, second through fourth segments also blue-iridescent anterolaterally, though much less distinctly than in first segment. Petiole not visible in lateral view, posterior margin of segment subtriangular in dorsal view. First through fourth gastral segments with cuticle smooth other than sculptured region laterally on first segment, and without setae on dorsal side, with at least one transverse row of setae on lateral and ventral sides; from fifth segment back, setae also present on dorsal and ventral surfaces, and cuticle lightly reticulate. Cercus with three setae of subequal length. Ovipositor sheaths extend slightly beyond end of eighth gastral segment, setose. Ovipositor often exserted just beyond end of ovipositor sheaths in dry specimens.

Male (Figs 4e–g; 5b, d, f): Overall similar to female except for antennae and sexual differences, and typically smaller. Pattern of infuscations on wings almost identical to female. Coloration also similar to the female, though some, especially smaller individuals, slightly darker.

Length: 0.60–1.00 mm; (allotype 0.95 mm)

Head (Figs 4e–g; 5f): As in female with exception of antenna and slight variation in coloration. Stripes on vertex and spots on inner orbits typically less distinctly separated, especially in smaller individuals, sometimes resulting in head as a whole appearing more dark-colored.

Antenna as in Fig. 5f. Scape light brown, lighter basally and apically, and widened medially with sensory plaque on ventral side; pedicel metallic dark green; all other segments dark brown. Funicle segments each with basal whorl of forward-pointing setae approximately equal in length to the respective segment, ending at base of next segment. F1 not

nodose, closely connected to F2. F2–F4 nodose, apical petiole longest in F2 and short in F4. Clava formed from three fused segments, subconical. Ratios of antennal segments approximately Scape (L:W) : Pedicel (L:W) : F1 (L:W) : F2 (L:W) : F3 (L:W) : F4 (L:W) : Clava (L:W) = (3.7:1.1) : (1.5:1.0) : (1.0:1.4) : (1.7:1.4) : (1.7:1.4) : (1.6:1.6) : (3.4:1.8).

Mesosoma (Fig. 4e, f) as in female, though coloration can be somewhat darker in smaller individuals, with the dark stripes running somewhat together. *Forewing and hindwing* (Fig. 5b, d) with same patterns as in female. *Legs* as in female. *Metasoma* (Fig. 4e) with cuticle shiny, dark iridescent purple-black in color, and smooth iridescent blue patch anterolaterally on first gastral segment.

Hosts. *Cis pacificus* and *Xylographus* sp., as described above. The *Xylographus* sp. appears not to have been previously recorded in Hawai‘i.

Known distribution. This species is known from O‘ahu, Hawai‘i.

CO1 sequence. GenBank Accession #PV405397

Etymology. The species name is Hawaiian, ‘ēlau‘ele‘ī, translated as *choice black treetops*. The sculpture and coloration of the head and mesosoma are reminiscent of treetops (‘ēlau) in a forest as seen from a high place above. The metasoma is blue-black/shiny black (‘ele‘ī)—a choice color in Hawaiian culture.

Notes and variation. Very little variation was observed in the pattern of infuscations on the forewing among collected specimens. When variation was observed, it was in slight differences in the shape of the jagged areas: there is occasionally a hint of an infuscation pointing towards the most basal brown spot on the parastigma from the basally projecting part of the middle band near where it intersects the cubital setal line, which if completed would be similar to that found in *A. micans*; the jagged region that makes up the basal margin of the infuscation emerging from the stigma is also slightly variable in shape, and if extended to connect to the medial band would be reminiscent of *A. bachmaieri*. In all specimens of *A. elauelei* collected and examined in this study, the topology of the infuscations was never observed to be different than reported here; there was always a very clear hyaline area separating the regions of infuscation.

This species is possibly closest morphologically to *A. micans*. Neser (2012) collected many individuals of *A. micans* from a variety of locations in South Africa, but reports that the pattern of infuscations on the forewing of females was very consistent among them. The variety of locations from which *A. elauelei* was collected in this study was not as varied, but individuals were also very consistent in the pattern of infuscations on the forewing, and even with the slight variation among specimens, there was little or no suggestion of a gradient between what was observed in specimens collected in Hawai‘i and *A. micans* reported by Neser (2012). *Astichus micans* males are reported by Neser (2012) to have reduced wing patterns, while wing patterns of males of *A. elauelei* were equally as developed as the females, even in small individuals. Among described species, the wing pattern of *A. elauelei* is closest to *A. naiadis*, though the coloration of the antennae, among other characters, readily distinguishes these species. Moreover, the patterns on the forewing may be a meaningful way to distinguish species of *Astichus* even when the differences are somewhat subtle and suggestive of gradation, as the patterns on the forewing over the whole genus vary greatly but, upon close examination, can largely be seen as variations on a general

pattern, with certain regions of the pattern becoming manifest and varying in intensity among the different species.

This species fits closely in the subgenus *Closteromphale* as defined by Bouček (1963, 1988).

Materials examined.

Holotype: ♀; Hawaiian Islands, O‘ahu, Palikea; 21.4145°N, 158.0999°W, 900 m; 9.vii.2020 ex *Fuscoporia gilva* on *Schinus terebinthifolia*, with *Cis* spp.; D. Honsberger (UHIM)

Allotype: ♂; same data as holotype (UHIM)

Paratypes: 30♀, 17♂. Hawaiian Islands, O‘ahu, Mānoa; 21.2954°N, 157.8145°W, 15 m; 17.v.2019; ex *Earliella scabrosa* on *Ficus microcarpa*; D. Honsberger; 3♂ (1 UHIM, 1 BPBM, 1 NHMUK) • Hawaiian Islands, O‘ahu, Mānoa; 21.2954°N, 157.8145°W, 15 m; 1.v.2020; ex *Xylographus* sp. in *Earliella scabrosa* on *Ficus microcarpa*; D. Honsberger; 2♀ (1 UHIM, 1 NHMUK) • Same data as holotype and allotype; 17♀, 6♂ (5♀, 2♂ UHIM; 6♀, 2♂ BPBM; 6♀, 2♂ NHMUK) • Hawaiian Islands, O‘ahu, Wa‘ahila; 21.3213°N, 157.7915°W, 360 m; 20.x.2020; ex *Fuscoporia gilva* on *Psidium cattleianum*, with *Cis* spp.; D. Honsberger; 3♀, 1♂ (BPBM) • Hawaiian Islands, O‘ahu, Wa‘ahila; 20.x.2020; ex polypores on fallen logs; D. Honsberger; 8♀, 6♂ (3♀, 2♂ UHIM; 3♀, 2♂ BPBM; 2♀, 2♂ NHMUK)

Astichus elauuli Honsberger & Lorenzo-Elarco sp. nov.

(Figs 6, 7)

Diagnosis: *Female*. Coloration and stripes as in Fig. 6a, b. Forewing with pattern of infuscations as in Fig. 7a. Antenna as in Fig. 7e, with F1, F3 except for its apex, F4, and the apical 1/3 of clava yellow, the rest brown. Short scale-like setae on head, on posterior of pronotum dorsally, and on mesoscutum. *Male*. Forewing with patterns as in Fig. 7b. Coloration of head and mesosoma variable, following a similar pattern to the female but with the dark stripes wider, especially in smaller individuals, the smallest individuals appearing almost completely metallic black in color. Antenna as in Fig. 7f, F2–4 nodose with the apical petiole longer than the node, F5 distinct from the clava, and each funicular segment with a whorl of setae substantially longer than the respective segment. The pattern on the forewing of females, especially of the apical infuscation, is unique from all other known *Astichus*, and can be used to readily distinguish this species. Since males are not known or described from many *Astichus* species, we refer their identification among all *Astichus* to the main description, but are easily distinguished from *A. elauelei*, the other species in Hawai‘i, also by pattern on the forewing.

Female (Figs 6a–d; 7a, c, e, g–i):

Length: 1.10–2.20 mm; holotype 1.85 mm

Head (Figs 6a, b, d; 7e): Iridescent green, gold, copper patterns of finely alveolate sculpture. Vertex with four dark longitudinal stripes; two begin on either side of white crossband at apex of scrobal depression and curve to posterior ocelli, then run straight back to posterior of vertex; a less distinct line emerges from cuticle on margin of compound eye approximately even with posterior ocelli and progresses the short distance to posterior of vertex. Scrobal groove delimited dorsally by carina and white crossband; white band approximately evenly thick along its length. Iridescence present on most of head somewhat abruptly transitions to light brown with smoother sculpture on lower face below toruli and on gena, this brown area extending higher on gena than on face.

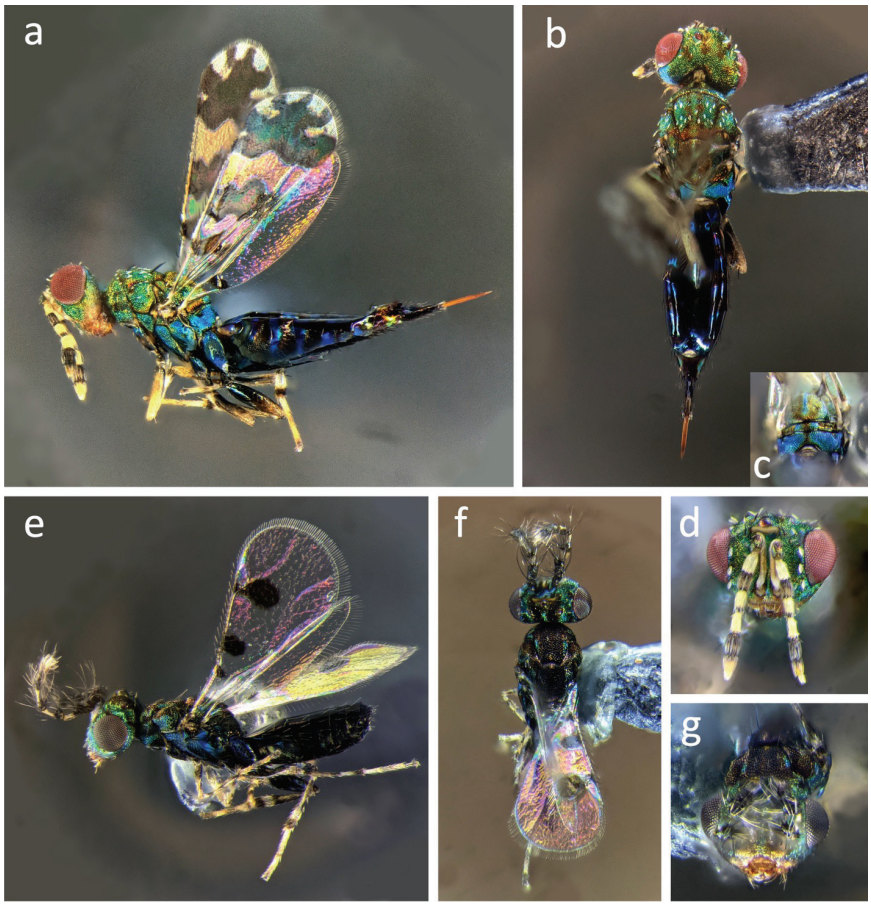

Figure 6. *Astichus elauuli* sp. nov. holotype ♀ (**a–d**) and allotype ♂ (**e–g**). **a, e:** side view. **b, f:** dorsal view. **c:** propodeum. **d, g**: head.

Clypeus also similarly light brown and with smooth sculpture. Scale-like light colored setae evenly spaced along inner orbit, from approximately even with top of interscrobal ridge around to posterior of vertex. A few similarly shaped but smaller setae on face just lateral to margin of scrobal depression; vertex also with scale-like setae. Longer dark colored setae lateral of white crossband at apex of scrobal depression, and on either side of anterior ocellus.

Antenna as in Fig. 7e. Scape brown medially and whitish basally and apically; pedicel dark metallic green-brown; F2, very apex of F3, and basal 2/3 of 3-segmented clava brown; F1, F3 except for its apex, F4, and apical 1/3 of clava yellow. F2 subrectangular and longer than wide; F1, F3, and especially F4 more rounded and also longer than wide. Length and width ratio of antennal segments approximately Scape (L:W) : Pedicel (L:W) : F1 (L:W) : F2 (L:W) : F3 (L:W) : F4 (L:W) : Clava (L:W) = (3.5:0.7) : (1.2:0.7) : (1.0:0.7) : (1.1:0.8) : (1.3:0.8) : (1.3:1.0): (3.0:1.1).

Mesosoma (Fig. 6a–c): Metallic,

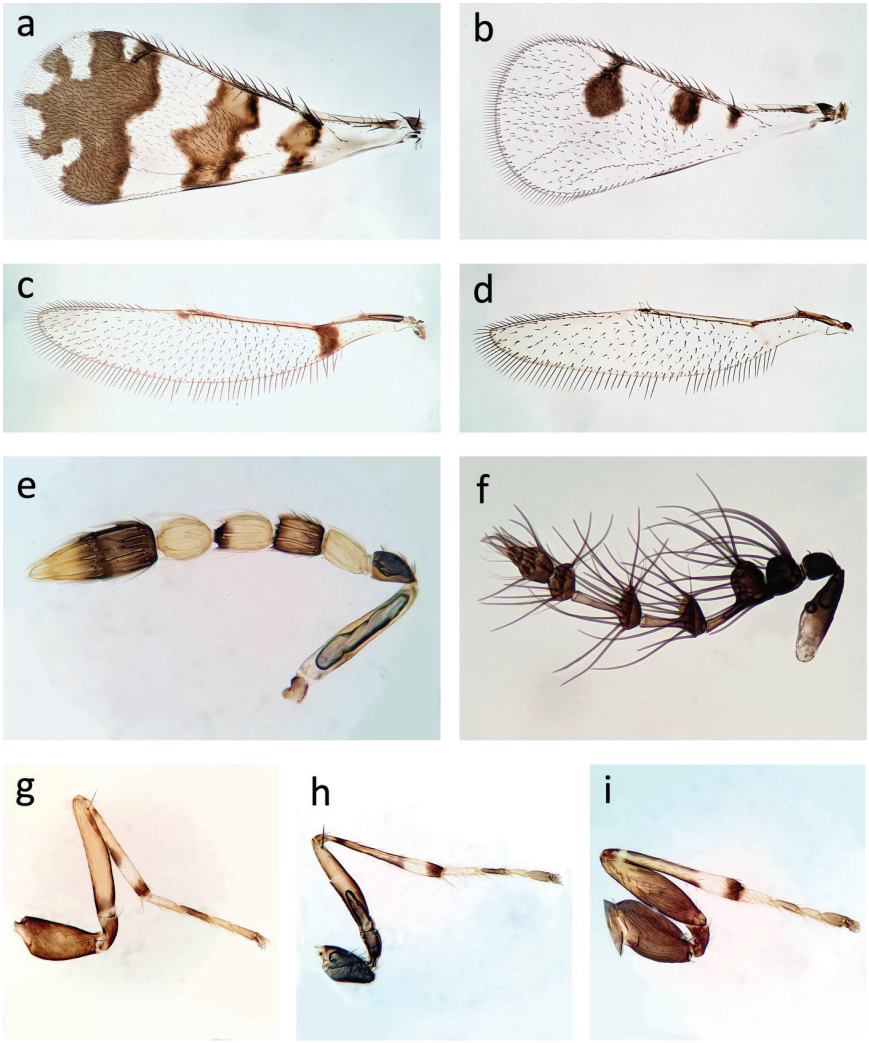

Figure 7. *Astichus elauuli* sp. nov. **a:** forewing ♀. **b:** forewing ♂. **c:** hindwing ♀. **d:** hindwing ♂. **e:** antenna ♀. **f:** antenna ♂. **g:** foreleg ♀. **h:** midleg ♀. **i:** hindleg ♀.

iridescent patterns of blue, green, copper, gold, and purple with alveolate sculpture. Colors generally darkening from dorsal to ventral (with exception of dark longitudinal stripes); pronotum blue-green, mesoscutum light blue, scutellum blue-copper and purple largely defined by the longitudinal stripes on it, metanotum with dorsellum blue and lateral regions copper-gold, propodeum blue, sides of mesosoma blue-green fading to dark purple posteriorly, coxae and ventral surfaces dark purple. Distinct dark longitudinal stripes on mesosoma, as in Fig. 6a–c. Sculpture in general evenly coarse over dorsal and lateral surfaces, except for mesopleuron where alveolate sculpture fades to polished,

weaker reticulations posteroventrally, and coxae with similarly weaker reticulations. Pronotal collar thin, with row of small, light colored, scale-like setae on posterior margin mesal of lateral panel. Midlobe of mesoscutum with two pairs of long, thin black setae 1/4 and 2/3 the distance between pronotum and transscutal suture; light colored scale-like setae in transverse rows just anterior of posterior pair of long setae, and even with anterior pair of long setae but only laterally. Lateral lobe of mesoscutum also with scale-like and longer thick light-colored setae. Scutellum without scale-like setae. Propodeum narrows mesally, posterior margin smoothly incurved, propodeum longer than dorsellum on medial line. Propodeum not elevated medially. Length of propodeum on medial line 0.20 times its width in dorsal view, and 0.26 times distance between propodeal spiracles.

Forewing: As in Fig. 7a, with three disjunct regions of infuscation separated by subhyaline wing membrane, in the following pattern. Dark brown band emerging from parastigma and extending to posterior wing margin, with jagged, variable margins, though most apically extended just anterior of cubital setal line. Dark band emerging from marginal vein beginning basally at approximately first admarginal seta; continuing as jagged band to posterior wing margin. Dark pattern at apex of the wing, solid medially and reaching wing margin at six sections as in Fig. 7a; hyaline areas between the five posteroapical infuscate sections subequal in length as measured around wing margin. Some variation in shape of patterns occurs in the exact form of the jagged margins of the two basal infuscations, and in thickness of arms of apical infuscation, though topology is unchanged.

Wing membrane setose apical of basal margin of medial dark band, except for speculum, which narrows near last admarginal seta. Non-setose gap between cubital setal line and subcubital setal line ends at base of apical infuscation, just basal of where trailing edge of wing begins to curve; cubital setal line curved away from wing margin apical of medial dark band, resulting in the non-setose gap substantially widening apically. Row of admarginal setae extends approximately length of middle third of marginal vein. Postmarginal and stigmal veins subequal in length; stigmal vein emerges from marginal vein at approximately 45° angle.

Hindwing (Fig. 7c): Membrane subhyaline with incurved arc-shaped infuscation extending from parastigma to posterior margin of wing. Marginal setae on trailing edge slightly less than 1/3 maximum width of wing.

Legs (Fig. 7g–i): Coxae with weakly reticulate sculpture, metallic iridescent blue-black. Femora and tibiae with patterns of brown and yellow, pattern varying slightly among individuals, but in general as in Fig. 7g–i. Tarsi with first segment yellow, second segment brown, third segment yellow, and fourth segment yellow-brown; protarsus with second segment longest, followed by fourth, first, and third; meso- and metatarsi with first through third segments of all legs decreasing in length, fourth segment subequal in length to second.

Metasoma (Fig. 6a, b): Gaster generally shiny, dark iridescent blue-purple-black; first gastral segment with light brown patch anterolaterally, first through fifth gastral segments with blue-purple iridescence anterior of setae and smooth to weakly reticulate sculpture. Petiole not visible in lateral view, posterior margin of segment rounded in dorsal view. Cercus with three setae of subequal length. First through fourth gastral segments each with transverse row of setae on lateral and ventral sides, and without setae dorsally;

from fifth segment back, transverse row of setae continues over dorsal surfaces as well, and ventral surfaces become more setose. Ovipositor sheaths extend past seventh gastral segment, approximately double the dorsal length of eighth gastral segment, setose. Ovipositor sometimes exserted past this in dry specimens.

Male (Figs. 6e–g; 7b, d, f)**:** Substantially dimorphic from female in pattern on wings and antennae. Coloration varies among individuals, with larger individuals more similar to females, though with slightly wider dorsal stripes; stripes generally wider relative to the body size in smaller individuals, smallest individuals with stripes so wide that their whole bodies are iridescent black in color.

Length: 0.60–1.55 mm; (allotype 1.10 mm)

Head (Figs. 6e–g; 7f): As in female except: longitudinal dark stripes on vertex wider, especially the two medial stripes, which in some individuals run together; lacking scale-like setae on inner orbit and vertex, with only thin light colored setae on face and vertex, and slightly longer dark colored setae on lateral margins of white crossband at apex of scrobal groove and around ocelli.

Antenna as in Fig. 7f with 5-segmented funicle, and 2-segmented club. Scape light brown, lighter basally and apically, widened medially with sensory plaque on ventral side; pedicel slightly metallic dark green; flagellomeres brown. F1 not nodose, connected closely to F2. F2–F4 apically nodose, petioles subequal to or longer than width of respective segment; F2 basally globular with apical petiole projecting from ventral side; F3 and F4 with globular part wider than long and petiole projecting more medially, overall mushroom-shaped. F5 not nodose, distinctly tapering but somewhat broadly connected to clava. Clava formed from two fused segments. Funicle segments each with whorl of long setae of length such that if pointing forward they would extend approximately to apex of next segment. Length and width ratio of antennal segments approximately Scape (L:W) : Pedicel (L:W) : F1 (L:W) : F2 (L:W) : F3 (L:W) : F4 (L:W) : F5 (L:W) : Clava (L:W) = (2.9:0.9) : (1.0:0.8) : (1.0:1.1) : (2.2:1.3) : (1.9:1.2) : (2.1:1.2) : (0.8:1.1) : (1.5:1.1)

Mesosoma (Fig. 6e, f): As in female except for differences in coloration and pattern of setae. Coloration variable, but usually darker than in females, especially on dorsum, with longitudinal stripes wider and often running together. Typically, larger individuals more brightly colored, as in females, smaller individuals darker than allotype, smallest with no remaining blue or green, and only hints of copper color where stripes fade into each other. Lacking light colored scale-like setae as found on females, but with short, thin setae on posterior margin of pronotum and sparsely on mesoscutum.

Forewing (Fig. 7b): Membrane subhyaline with three dark spots, all connected to margin of leading edge of wing and extending posteriorly about half the distance to posterior edge. Basal spot extends as short band from parastigma. Medial spot extends from marginal vein near basal admarginal seta, subrectangular though somewhat irregularly shaped, in some individuals with less intensely infuscate posterior projection sometimes ending in a spot just anterior of cubital setal line. Apical spot droplet-shaped, globular posteriorly, and narrowly connected to wing margin at base of stigmal vein, covering stigmal vein. Visible setal lines emerging as continuation of stigmal vein, as continuation of uncus, and beginning in middle of wing curving posteroapically. As in female, subcubital setal line curves away from wing margin apically, so

nonsetose gap between cubital and subcubital setal lines widens posteriorly.

Hindwing (Fig. 7d): As in female except mostly subhyaline, with at most a hint of infuscation near base, which, if present at all, is indistinct.

Legs as in female. *Metasoma* (Fig. 6e) with cuticle shiny, dark iridescent purple-black in color.

Hosts. *Cis pacificus* is the highly suspected but unconfirmed host. Hundreds of *A. elauuli* were observed to emerge from a collection of polypores from a single tree, a sample of which was dissected, showing *C. pacificus* to be by far the dominant inhabitant.

Known distribution. This species is known from Oʻahu, Hawaiʻi

CO1 sequence. GenBank Accession #PV404398

Etymology. The species name is Hawaiian, ʻēlauuli, translated as *dark-colored treetops*. The sculpture and coloration of the head and mesosoma are reminiscent of tree tops (ʻēlau) in a forest as seen from a high place above. The wasp's metasoma boasts variations of blue tones—the dark (uli) being the most prominent.

ʻĒlauʻeleʻī (*Astichus elauelei*) and ʻēlauuli (*Astichus elauuli*) share *ʻēlau* for their similarities in color and sculpture, and are made distinguishable by the following modifiers (*ʻeleʻī* / *uli*).

Notes and variation. There is only slight variation in the coloration of the head and mesosoma in females, but occasionally much greater variation in males. In males, the thickness of the longitudinal stripes on the mesosomal dorsum is typically wider than in females, and in small individuals can approach an almost complete darkening of the head and mesosoma, leaving only hints of gold stripes between where the lines have merged. The posterior margin of the middle infuscation in the forewing of males is also subject to some variation. In most individuals, the posterior margin of the infuscation is somewhat rounded, but in some individuals, a line extends somewhat posteriorly from it, sometimes ending in a small, slightly darkened spot just anterior of the cubital setal line. The pattern of infuscations in the female forewing is remarkably consistent among individuals, given its complexity.

The sexual dimorphism in this species in patterns on the wings and coloration is greater than is known for other species of *Astichus*. We are confident that these are in fact the two sexes of a single species for two reasons: (1) From the polypores from which we obtained the vast majority of the specimens of this species, *F. gilva* on *Psidium cattleianum* on the slopes of Waʻahila Ridge, all female *Astichus* that emerged were as the above described females, and all male *Astichus* were as the above described males, with the exception of a small number of *A. elauelei* that also emerged with them. (2) The CO1 gene was amplified and sequenced from two females and two males (primers and PCR protocol as in Folmer *et al.* (1994)), and gave a 100% match between the females and males.

This species fits closely in the subgenus *Closteromphale* as in Bouček (1963, 1988), though as noted by Neser (2012), the subgenus may not be completely well-defined.

Materials examined.

Holotype: ♀; Hawaiian Islands, Oʻahu, Waʻahila; 21.3213°N, 157.7915°W, 360 m; 20.x.2020; ex *Fuscoporia gilva* on *Psidium cattleianum,* with *Cis* spp.; D. Honsberger (UHIM)

Allotype: ♂; same data as holotype (UHIM)

Paratypes: 10♀, 16♂. Hawaiian Islands, Oʻahu, Kahana Bay; 21.5572°N, 157.8783°W; 20.viii.2019; ex polypores on *Schefflera actinophylla*; D. Honsberger;

1♀, 1♂; (BPBM) • Hawaiian Islands, O‘ahu, Wa‘ahila Ridge; 4.x.2019 ex *Fuscoporia gilva* on *Acacia koa* and *Schefflera actinophylla*, with *Cis* spp.; D. Honsberger; 2♂ (NHMUK) • Same data as holotype and allotype; 7♀, 13♂ (2♀, 4♂ UHIM; 2♀, 5♂ BPBM; 3♀, 4♂ NHMUK) • Hawaiian Islands, O‘ahu, Wa‘ahila; 20.x.2020; ex polypores on fallen logs; D. Honsberger; 1♀ (UHIM) • Hawaiian Islands, O‘ahu, Poamoho Ridge; 21.5311°N, 157.9524°W, 570 m; 18.xii.2020; ex *Fuscoporia gilva* on *Acacia koa,* with *Cis* spp.; D. Honsberger; 1♀ (UHIM)

Discussion

Here we report two new species of *Astichus* on O‘ahu and show the existence of a parasitoid-host association between *Astichus elauelei* and the two ciids *Cis pacificus* and a *Xylographus* sp. The association was found for *C. pacificus* by direct observation of parasitized larvae in *F. gilva* basidiomes. It was found for the *Xylographus* sp. by use of sentinel colonies composed of *E. scabrosa* basidiomes, each infested with a single, different ciid species, the spectrum of ciid species utilized including all those found in the same species of polypore at the same location from which *A. elauelei* had been observed emerging. The *Xylographus* sp. found in these polypores on *F. microcarpa* trees appears to be a new record for the Hawaiian Islands, the genus *Xylographus* being previously unrecorded, and is very likely adventive to the islands. *Cis pacificus*, which is attacked by *A. elauelei* and presumably also by *A. elauuli*, is a Hawaiian endemic. Many of the basidiomes in which we found both of these *Astichus* spp. were densely populated by *C. pacificus,* and where parasitism was observed, parasitized larvae appeared to be few relative to the large numbers of healthy ones. Such observations were only made a small number of times and were by no means an extensive study of Ciidae or polypores in the variety of ecosystems present in Hawai‘i, and thus do not preclude that their effect on populations is different in other environments. *Astichus elauelei* was in this study only confirmed to utilize two ciid species, but given that those species are in different tribes and were found inhabiting two dissimilar polypores, it seems likely that this parasitoid is somewhat polyphagous and attacks other species of Ciidae as well. Both appear to be cryptoparasitic, given that both adults and parasitized larvae were found at substantial depth within the basidiomes. As is true in general for the genus, these *Astichus* spp. have so far been associated only with polypores, but nothing beyond this is known about their host searching behavior. If based on cues specific to ciids in polypores, Hawaiian endemic species that do not inhabit polypores may possibly be safe from attack. Ciidae make up an important endemic radiation in Hawai‘i, and knowledge of their natural enemies and nonnative relatives are important to be aware of for the health of our forests. And if for no other reason, these observations may be of note just because of the beauty of these creatures and to illuminate the fascinating and readily observable world inside fungi growing on decaying trees.

Acknowledgments

We acknowledge that this research took place on the mokupuni of O‘ahu in the ahupua‘a of Waikīkī in the moku of Kona, near the boundary between Kamananui and Pa‘ala‘a in the moku of Waialua, near the boundary of Nānākuli and Lualualei in the moku of Wai‘anae, Honouliuli in the moku of ‘Ewa, and Kahana in the moku of Ko‘olauloa, the ancestral and traditional lands of Native Hawaiian people. We

thank Dmitry Telnov for providing images of a syntype of *C. pacificus* held in the BMNH, and Adrienne Antonsen and Lisha Jasper for providing images of some Ciidae type specimens held in the BPBM, kindly shared with Cristiano Lopes-Andrade by Igor Souza-Gonçalves. We thank Hawai'i Department of Agriculture and Biosecurity and USDA-ARS for providing funding to support this research. Financial support for C. Lopes-Andrade was provided by Conselho Nacional de Desenvolvimento Cientifico e Tecnológico do Brasil (CNPq; research grant 3004339/2022-9).

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